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Ministry
of
Education
Ontario

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Curriculum Guideline

Science

Intermediate and Senior Divisions

1987

Part 13

Chemistry

Grade 11, Advanced Level and the OAC

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Introduction

The Parts of the Guideline

This document is Part 13 of a fifteen-part curriculum guideline that outlines the science program for the Intermediate and Senior Divisions in Ontario schools and describes the science courses that can be offered (see the list of courses and their course codes in Appendix A). The term *guideline* refers to the entire set of fifteen parts.

This part must be read and implemented in conjunction with Part 1, *Program Outline and Policy*. When implementing the courses that are described in this document, teachers are to incorporate the many policies and features outlined in Part 1, which will enable them to interpret the overall intent and expectations of the Ministry of Education in the science program. The table of contents for Part 1 is given in Appendix B at the end of this document so that the reader may have ready access to the list of chapters and topics therein.

The provincial science program for the Intermediate and Senior Divisions comprises the courses described in Parts 2 to 15. These come under the framework and policy set forth in Part 1. The entire science guideline consists of the following fifteen parts:

Part 1: Program Outline and Policy
Part 2: Science, Grades 7 and 8
Part 3: Science, Grades 9 and 10, General Level
Part 4: Science, Grades 9 and 10, Advanced Level
Part 5: Science, Grades 9 and 10, Basic Level
Part 6: Science, Grades 11 and 12, Basic Level
Part 7: Environmental Science, Grades 10 to 12, General Level
Part 8: Environmental Science, Grades 10 and 12, Advanced Level
Part 9: Applied Biology and Applied Chemistry, Grade 11, General Level
Part 10: Applied Physics and Technological Science, Grade 12, General Level
Part 11: Geology, Grade 12, General and Advanced Levels
Part 12: Biology, Grade 11, Advanced Level, and the OAC
Part 13: Chemistry, Grade 11, Advanced Level, and the OAC
Part 14: Physics, Grade 12, Advanced Level, and the OAC
Part 15: Science in Society, OAC

The chart on the next page indicates the twenty-eight science guideline courses that may be offered in Grades 7 to 12 and at the OAC level.

Policies and Features That Apply Across the Science Program

Part 1 of the guideline specifies a great number of the policies and features that are to be integrated into the design of the science program in the Intermediate and Senior Divisions. There are too many of them to describe in full in each of Parts 2 to 15, but the following points will give the reader some idea of the scope that is involved. They include:

- information about the science credits that are required for the earning of the Ontario Secondary School Diploma;
- a list of science courses that are prerequisite to other science courses;
- the policy regarding mandatory student activities in the science laboratory;
- a list of the aims of the science curriculum and the various emphases that may be used to blend these aims with scientific content;
- policy governing time allocations for units of study and the order in which core and optional units may be taught;
- stipulations about locally designed units;
- suggestions about preferred routes that students might take through the science program in a secondary school;
- recommendations related to exceptional students, individualized instruction, life-management skills, career awareness, the role and evaluation of language in science courses, and a balanced perspective on the role of both girls and boys in science;
- recommendations on the introduction and handling of sensitive issues;
- specific suggestions about resources for the teaching of science;

Authorized Science Guideline Courses, Intermediate and Senior Divisions

	Basic Level	General Level	Advanced Level
Grade 7		Science	
Grade 8		Science	
Grade 9	Science (SNC1B)	Science (SNC1G)	Science (SNC1A)
Grade 10	Science (SNC2B)	Science (SNC2G) Environmental Science (SEN2G)	Science (SNC2A) Environmental Science (SEN2A)
Grade 11	Science (SNC3B)	Applied Biology (SBA3G) Applied Chemistry (SCA3G) Environmental Science (SEN3G)	Biology (SBI3A) Chemistry (SCH3A)
Grade 12	Science (SNC4B)	Environmental Science (SEN4G) Geology (SGE4G) Applied Physics (SPA4G) Technological Science (STE4G)	Environmental Science (SEN4A) Geology (SGE4A)* Physics (SPH4A)
OACs			Biology (SBI0A) *Prerequisite* – Biology (SBI3A) Chemistry (SCH0A) *Prerequisite* – Chemistry (SCH3A) Physics (SPH0A) *Prerequisite* – Physics (SPH4A) Science in Society (SSO0A) *Prerequisite – One of:* Biology (SBI3A) Chemistry (SCH3A) Environmental Science (SEN4A) Geology (SGE4A)* Physics (SPH4A)

*Since the Grade 12 advanced-level geology course described in the guideline (see Part 11) may be taught under the aegis of a geography department as Geology (GGE4A) – note the course-code change – then either Geology (SGE4A) or Geology (GGE4A) may count as a prerequisite to Science in Society (SSO0A).

- ideas about different modes of delivering science courses, including the co-operative education mode;
- policy pertaining to the significant role to be played by measurement and metric units in science courses;
- stipulations related to the treatment of symbols, significant digits, and mathematical problem solving;
- recommendations concerning the roles to be played by calculators and computers in science courses;
- specific directions about safety;
- policy and principles pertaining to the evaluation of student achievement;
- policy regarding differences in the treatment of science courses at the three levels of difficulty;
- many suggestions about implementing the science program.

It cannot be emphasized strongly enough that teachers of science must integrate the policy and recommendations outlined in Part 1 with the teaching of science and cannot simply rely on the course descriptions given in Parts 2 to 15 of the guideline.

The Science Curriculum Continuum

By the time students have reached the Senior Division, they will have experienced first a *unified* approach in the Primary and Junior Divisions, in which science is related to a number of other subject areas, and then a *diversified* approach to a mosaic of science disciplines – biology, chemistry, physics, and environmental science – in the Intermediate Division. In the Senior Division, they are provided with a *specialized* approach, in which the science courses deal with a single discipline at a time.

Although these approaches – unified, diversified, and specialized – provide different ways of dealing with the subject, the intention is to ensure that there is a continuum throughout the years. The two advanced-level courses in chemistry, the Grade 11 course and the OAC, build on the physical science units of the advanced-level courses in the Intermediate years. It is essential that students who wish to attend university and continue their study of chemistry include Grade 11 advanced-level chemistry and the chemistry OAC in their secondary school program.

Chemistry teachers should be aware of the subject matter contained in the physical science units of the Intermediate Division courses and of the way in which Senior chemistry, biology, and physics courses relate to one another.

In all science courses the core units and the prescribed number of optional units, if any, are to be included. The time allocation for each unit of study should act as a guide in helping teachers devote an appropriate amount of time to each of the units in a course. This is important in view of the continuum from one course to another and to postsecondary science programs.

Compulsory and Prerequisite Courses

In the secondary school program two science courses are required among the compulsory subjects that are necessary for the earning of the Ontario Secondary School Diploma. It is, therefore, anticipated that most of the students who enrol in Senior Division advanced-level chemistry courses will have taken Grade 9 and 10 science also at the advanced level.

Chemistry, Grade 11, Advanced Level is a prerequisite to Chemistry, OAC. Principals may waive this requirement if the student has taken a course that may be considered to be equivalent to the prerequisite or if there is good reason to believe that the student can adequately cope with Chemistry, OAC in preparation for university.

Curriculum Emphases

It is recommended that teachers organize each of the courses described in this document around a particular curriculum emphasis or set of emphases. Such emphases give the curriculum a special focus that can be introduced in addition to the content and processes outlined in the courses. This approach is discussed in subsection 3.4, “Curriculum Emphases – Blending Curriculum Aims With Content”, of Part 1 of the science guideline. In table 2 of that subsection a list of emphases is given. These emphases will enhance the development of the science courses described in this document. A particular emphasis that is stressed throughout an entire course or for one or more units at a time needs to be highlighted so that it becomes a focal or integrating theme.

Student Activities

In each unit of study there is a section entitled "Student Activities". This section indicates the *mandatory* laboratory activities required of students. Teachers may substitute *equivalent* laboratory activities where appropriate. Those activities that are actually to be performed by students themselves are marked with asterisks. If time and circumstances permit, the teacher should encourage students to do some or all of the unmarked activities as well. However, such activities may be demonstrated by a student or the teacher or may be discussed in conjunction with a textbook, film, computer program, or other learning material used as a resource. In any event, the scientific concepts and principles related to such unmarked activities and identified in the objectives of the unit of study shall be considered to be part of the prescribed course.

Generally, the best approach to the teaching of science is to ensure that the content develops directly from related student activities. In each unit of study the skills and processes of scientific work should be presented as the central component, from which the subject matter, applications, and implications emerge.

Safety

Safety awareness must be developed in all science students. Constant attention to accident prevention is to be stressed in all student activities and teacher demonstrations in the laboratory. Section 9, "Safety", in Part 1 of the science guideline contains the following comprehensive subsections:

- Safety in the Laboratory
- Some Recommended Safety Procedures
- Animal Care in Science Courses
- The Safe Use of Plants

In each unit of study, subsection 6, "Safety Considerations", acts as a reminder of some of the safety features that pertain to the unit in question. General reference, however, should constantly be made to the safety section in Part 1. Schools must always remain on the alert in regards to safety and maintain an up-to-date safety-awareness program.

Sensitive Issues

The curriculum outlined in this science guideline places a distinct emphasis on the science-technology-society connection. For this reason scientific applications and societal implications are mandatory components of each unit of study. In addition, Part 1 of the guideline underlines the need to incorporate morals/values education in science courses. Undoubtedly, this will give rise to the discussion of some sensitive issues.

Such discussions are important. Generally, they should be focused and should provide an open forum for the expression of different viewpoints. In this regard teachers of science are urged to familiarize themselves with section 10, "Values in Science Education", of Part 1 of the guideline and to pay particular attention to the principles to be observed when dealing with sensitive issues in the science curriculum. These principles are mentioned in subsection 10.2 of Part 1.

Evaluation of Student Achievement

Particular attention must be paid to the opening policy statements made in section 14, "Evaluation", in Part 1 of the guideline. The evaluation of student achievement in all Intermediate and Senior Division science courses must include certain components as follows:

- laboratory activities and reports .... at least 15 per cent

and in addition for the OACs:

- independent study .... at least 10 per cent
- one or more formal examinations ....30 to 40 per cent

In each unit of study described in the courses outlined in this document, subsection 5, "Evaluation of Student Achievement", specifies certain items that must be included in students' term marks (exclusive of formal examinations) when their achievement is evaluated. In most units teachers are required to evaluate students' activities and related laboratory reports. However, the proportion of the mark assigned will vary from one teacher to another. In order that the experimental component of science be emphasized, the overall mark for an entire science course must include at least 15 per cent for the evaluation of student achievement in laboratory skills and reports.

Cross References

In the descriptions of each unit of study in the courses outlined in this document, cross references are provided in parentheses. These are included to provide some examples of the relationships that exist among the parts of the unit.

Particular Features of the Senior Advanced-Level Chemistry Courses

Units of Study and Their Time Allocations

The following charts provide an overview of the units of study in the Grade 11 advanced-level course and the OAC. They also indicate the time to be allotted to each unit.

Chemistry, Grade 11, Advanced Level (SCH3A)

Core Units of Study	Time Allocations
1. Matter	8 h
2. Elements and Chemical Bonding	20 h
3. Gases	15 h
4. Chemical Reactions	25 h
5. Chemical-Reaction Calculations	13 h
6. Solutions	20 h
7. Industry and Society	9 h
	110 h

Chemistry, OAC (SCH0A)

Core Units of Study	Time Allocations
Review	4 h
1. Organic Chemistry	15 h
2. Atomic Structure and Molecular Architecture	13 h
3. Energy and Rates in Chemical Reactions	20 h
4. Equilibrium – Introduction	12 h
5. Equilibrium – Applications	18 h
6. Redox and Electrochemistry	20 h
7. Independent Investigation	8 h
	110 h

Interrelationships Between the Two Courses

The two Senior advanced-level chemistry courses – Chemistry, Grade 11, Advanced Level and Chemistry, Ontario Academic Course (OAC) – form a continuum. The first course is prerequisite to the second. Teachers of either course should be thoroughly familiar with the subject material in both in order to ensure that overlap between them is minimal and that continuity is provided.

Both the Grade 11 course and the OAC emphasize a balance between substantive *content* and scientific *process*; these are supported by hands-on student activities. The two courses require a balance in *quantitative* and *qualitative* work. The former is accomplished through measurement, graphical analysis, and mathematical problem solving; the latter, through communication, both verbal and written, of ideas, concepts, findings, questions, and opinions. The use of appropriate language should be stressed. Balance must also be provided through a *science-technology-society* emphasis. Applications and societal implications, identified in each unit of study, should ensure that chemistry is perceived by the students to be a relevant human endeavour, influencing lives, societies, and nations.

Both chemistry courses should include references to careers in which chemistry plays a role. This should stimulate an interest in human participation in science and lead to some discussion of the work, responsibility, and influence of chemists. The achievements of Canadian and other chemists should be stressed from time to time.

Teachers of these two chemistry courses should impress students with the fact that they are surrounded by matter and that they are a part of, and interact with, that matter. In these courses students should also seek to understand and look for meaning in the interactions among scientists, industry, the environment, and all living things. Such meaning should help students to realize that chemistry can enhance life and be directed towards useful, positive, and peaceful purposes.

The Grade 11 Chemistry Course

Since some students will take only the Grade 11 course, and not the OAC, this is intended to be a survey course involving seven core units of study in chemistry. While the course offers an introductory treatment, it must also provide a foundation for students who wish to take further studies in chemistry at the OAC level. It permits coverage of a broad range of concepts rather than an in-depth treatment of a few.

The Grade 11 advanced-level chemistry course is designed to provide a fundamental background that will enable students to understand chemical concepts, handle chemicals intelligently and safely, and appreciate the applications and implications of chemistry in technology and society. This course will be related to the other sciences and will endeavour to raise students' awareness of matter, molecules, and atoms and the changes that occur among them.

Mathematical work, often in the form of balancing equations, is expected in the course, but it should not be structured excessively towards mathematical problem solving at the expense of other important objectives.

The Chemistry OAC

The OAC in chemistry is more rigorous than the Grade 11 course and treats some topics in greater depth. It is intended to prepare students for further studies in chemistry at the university level and therefore places more emphasis on mathematical problem solving than does its prerequisite course.

As the course progresses, problem solving should include some problems that involve concepts from two or more different units of study. This will help students to realize that various areas of chemistry can be interrelated and are often interdependent.

The OAC in chemistry provides students with the opportunity to further expand the content and processes introduced in the Grade 11 prerequisite course. The OAC pursues an in-depth treatment of the way in which matter changes and interacts. The subject matter is more theoretical but does contain ample opportunity for laboratory work. One aim is to prepare students for further studies in science at the postsecondary level. Special emphasis should be given to such features as hypothesizing, interpreting, problem solving, and decision making. Theoretical considerations should be interlaced with practical activities and the examination of technological applications and societal implications.

In the time allocations for the chemistry OAC there is provision for four hours to review relevant material from the Grade 11 advanced-level chemistry course. This time may be used as required during the study of various units.

It is recommended that core unit 1, "Organic Chemistry", be placed at the beginning of the chemistry OAC, although such placement is not mandatory. Some advantages of doing this include the following:

- As a new unit, it will capture student interest.
- It may be helpful for those students who are studying the biology OAC.
- It could be used effectively to review such concepts as chemical changes, bonding, and molecular structure.

Core unit 7, "Independent Investigation", should be introduced early in order to give students ample time to select an appropriate topic or topics and to obtain material from a variety of sources before formally beginning the investigation. Ample classroom time should also be made available to the students in order that they can do justice to the unit. At least 10 per cent of the total evaluation of student achievement in this course must be devoted to independent study.

For the chemistry OAC, the formal examination(s) required of all students and worth from 30 to 40 per cent of the final mark should contain a variety of types of questions, such as alternate-response, multiple-choice, and matching selected-response types; short-answer, completion, restricted- and extended-essay types; numerical types; and, where feasible, types that involve laboratory skills. The formal examination(s) may consist of written and laboratory components. These components may occur close together or weeks or months apart.

Metric Units in Senior Chemistry

In subsection 8.2 of Part 1 of the guideline, there is a list of metric units with which students are expected to be familiar by the end of Grade 10. In Senior Division courses, the list of metric units with which science students work will naturally expand.

The concept of coherently derived units should be understood by students in advanced-level Senior science courses. Coherency in a measurement system means that the derived units such as the cubic metre, joule, pascal, volt, joule per mole, and becquerel are formed by multiplying and dividing base units without using any numerical factor other than the number one. The joule is a coherent SI unit ($1\ \mathrm{J} = 1\ \mathrm{kg{\cdot}m^2/s^2}$); the calorie is not ($1\ \mathrm{cal} = 4.2\ \mathrm{kg{\cdot}m^2/s^2}$).

Chemistry teachers are urged to examine the list of primary units (base units plus those coherently derived from base units) mentioned in subsection 8.2 of Part 1. They should determine those that are appropriate for chemistry courses. Prefixed multiples and submultiples of the primary units must be selected as well. Appendix B in Part 1 may provide some help in making the selection.

Unit analysis is a topic that should be included in Senior science. Equations in chemistry lend themselves very well to illustrating the need to ensure that the units of measure on both sides of an equation are equivalent.

Chemistry Grade 11, Advanced Level (SCH3A)

Core Units

- Matter
- Elements and Chemical Bonding
- Gases
- Chemical Reactions
- Chemical-Reaction Calculations
- Solutions
- Industry and Society

(110 hours)

Core Unit 1

Matter

Time: 8 hours

All substances are made of matter. Matter is constantly changing, and thus its properties change; yet matter is conserved (or occasionally converted to energy). The purpose of this unit is to provide students with opportunities to review the chemical concepts studied in the Intermediate Division, to observe properties of and changes in matter, and to understand the role of scientific theories in seeking to explain what is observed.

This unit may be divided into topics such as the following:

- ▸ Review of terminology and elementary concepts
- ▸ Physical and chemical properties and changes
- ▸ The law of definite proportions
- ▸ Theories of the structure of the atom

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the order in the universe as demonstrated by the regularities of properties found in matter (2d, 2e);
b) an appreciation for the scientific theories used to explain regularities in the behaviour of matter;
c) a questioning attitude towards the atomic theory, which, like other scientific models, is tentative and has changed since it was first proposed (8b).

Skills. Students will have the opportunity to develop skill in:

a) observing and comparing the properties of various substances and identifying the characteristics that may be used to separate the components of mixtures (2a-2c);
b) using laboratory equipment (e.g., the Bunsen burner, filtration equipment, glassware) safely;
c) making inferences about particle size in various samples of matter and testing the inferences (2a-2c, 5a);
d) classifying samples of matter as mechanical mixtures, solutions, pure substances, elements, and compounds (2a-2c);
e) solving problems related to percentage composition by mass of a compound (2d,5b).

Knowledge. Students will be expected to:

a) review and recall the meaning of the following terms: states of matter, changes of state, homogeneous, heterogeneous, mechanical mixture, solution, solute, solvent, pure substance, element, compound, physical change, chemical change, reactant, product, law of conservation of mass;
b) differentiate between physical and chemical properties of matter and between qualitative and quantitative observations;
c) describe and explain common methods of separating the components of mixtures, including filtration, sedimentation, distillation, magnetization, flotation (2a, 2b);
d) describe experiments that illustrate physical and chemical changes (2a-2d);
e) name, write symbols for, and know simple characteristics of the first twenty elements and any other ten elements;
f) use symbols to show the atomic number and the mass number of an atom (e.g., $^{4}_{2}$He);
g) explain the law of definite proportions (constant composition) by using the atomic theory (2d);
h) briefly indicate the contributions of the following scientists to the development of the concept of the atom: Dalton, Rutherford, Chadwick, Bohr;
i) describe the atom as consisting of mostly empty space with a nucleus and electrons at various energy levels located around the nucleus;
j) indicate the similarities and differences among the electron, proton, and neutron with respect to their location in the atom, their mass, and their electrical charge;
k) define or indicate the meaning of the following: atomic number, mass number, atomic mass, isotope, radioisotope;
l) indicate the composition of the nucleus and, using the Bohr theory, indicate electron configurations for the first twenty elements (8b, 8c);
m) describe how line spectra of elements tend to support a model of the atom that has electrons at different energy levels (2e).

2. Student Activities

Students are to:

a) separate the components of a mixture by means of filtration;
*b) examine some physical and chemical properties of several common elements, such as calcium, carbon, iron, magnesium, oxygen, and sodium (6a);
*c) perform experiments to illustrate chemical changes, such as simple oxidation or precipitation (6a, 8a);
*d) experimentally verify the law of definite proportions;
e) observe the continuous spectrum of white light and the line spectra of two or three elements (6b).

3. Applications

a) Physical and chemical changes occur in the cooking and spoilage of food and in the bleaching of clothes.
b) The separation of mixtures by physical means is used in the metal-ore and dairy industries, to purify water, and to control air pollution.
c) In metallurgical industries, spectroscopic applications help to identify impurities.
d) Radioactive isotopes are used for carbon dating and for medical diagnosis and treatment.
e) Spectral analysis of the light from the stars is used to determine the elements found in stars.
f) Heavy water is used in the Candu reactor. It contains deuterium, a heavy hydrogen isotope.
g) The isotope cobalt-60 is used in the radiation treatment of cancer.

4. Societal Implications

a) Separation processes (e.g., extracting metals from ore) provide us with valuable products but may become more expensive because of an increasing need for better pollution controls.
b) Ontario has a broad distribution of ores, from which many materials are extracted. Many products are made from such materials.
c) Chemical processes may result in contamination of the environment. Even in small amounts, such contamination can be a major concern (e.g., dioxin in water).
d) The addition of small amounts of fluoride to water can help in the fight against tooth decay.
e) Oil spills produce mixtures that can be hazardous to the environment.
f) Radioactive isotopes have many beneficial uses (e.g., in the treatment of cancer, in smoke detectors, and in the sterilization of food).
g) Radioactive isotopes can pose disposal problems, some more serious than others.
h) Many mixtures are very important (e.g., paint, gasoline, foods).

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) laboratory work and related written reports, particularly in relation to the making and testing of inferences;
b) mathematical problem solving.

6. Safety Considerations

a) In selecting specific chemical reactions for student activities, the teacher must pay special attention to safety.
b) Students should be cautioned about the high voltage present when spectral lines are produced.

7. Possible Extensions

Some students might:

a) separate the components of mixtures containing three or more substances;
b) determine by electrolysis the percentage composition by volume of water;
c) synthesize zinc chloride from zinc and hydrochloric acid in order to determine the percentage composition by mass of zinc chloride;
d) discuss nuclear concepts in some depth (e.g., subatomic particles and particle accelerators);
e) discuss the relationship between radioactivity and nuclear stability;
f) solve problems related to the relative abundance of isotopes in nature.

8. Some Teaching Suggestions

a) Students can synthesize some compounds in order to increase their knowledge of some common chemicals and improve their laboratory skills.
b) The usefulness and limitations of theories should be stressed. The historical approach to the modern atom should leave students with the concept of the atom as a nucleus surrounded by electrons in various energy levels. The "fuzzy" nature of the electron position should be indicated. A discussion of the orbital model is not intended in this unit.
c) When students are learning the names and symbols of the elements and are drawing diagrams of them, samples of as many of the elements as is practical should be displayed.

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*See the subsection entitled "Student Activities" on page 6.

Core Unit 2

Elements and Chemical Bonding

Time: 20 hours

Although the universe contains an enormous number of different compounds, it is composed of relatively few elements. A study of the physical and chemical properties of the elements and their structures leads to an understanding of the nature and formation of compounds. The purpose of this unit is to provide students with opportunities to investigate trends in the properties of the elements that make up the periodic table, to develop an understanding of structure and bonding through the use of scientific models, and to acquire a basic knowledge of chemical reactions.

This unit may be divided into topics such as the following:

- Organization of elements
- The periodic table
- Lewis structures
- Ionic and covalent bonding

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the orderliness of the elements and the way in which their characteristics have an organized pattern (2a-2d, 8a, 8b);
b) a respect for the ability of atomic models to help explain the physical and chemical properties of elements and the formation of compounds (2e, 8c);
c) a curiosity about the nature of chemical bonding (2e).

Skills. Students will have the opportunity to develop skill in:

a) observing the similarities and differences among common elements of the periodic table (2a-2d, 8b);
b) classifying elements as metals or non-metals on the basis of physical and chemical characteristics (2c, 2d, 8a);
c) locating metals and non-metals from their positions in the periodic table;
d) drawing Lewis structures for simple atoms (5c);
e) using Lewis structures to predict the bonding of simple molecules (2e);
f) using appropriate language to describe their observations of the properties of some common elements (2a-2d);
g) interpreting experimental data and formulating generalizations (2a-2d);
h) predicting characteristics of elements, knowing their position in the periodic table (5b).

Knowledge. Students will be expected to:

a) list common metals and non-metals and some elements that have properties of both (2a-2d, 8a);
b) define or state the meaning of the following terms: ionization energy, chemical bonding, periodicity, covalent bond, ionic bond;
c) use Lewis structures to explain simple bonding and molecular structure (2e);
d) relate stable positive and negative ions and the reactivity of elements to their position in the periodic table (8d);
e) plot the ionization energies of the first twenty elements against their atomic numbers and relate this information to the periodic table;
f) state some trends in the reaction of metals with acids and oxygen (2c, 2d);
g) compare the activity of various metals and develop an activity series for them (2b-2d);
h) demonstrate with the aid of models that carbon may form long molecular chains (2e, 8c, 8e).

2. Student Activities

Students are to:

a) observe the properties of some elements (e.g., carbon, copper, nickel, oxygen, sodium, sulphur) in order to classify them as metals or non-metals;
*b) compare the rates of reactions of some alkali and alkaline earth metals in water and test the resulting solutions with litmus paper and another indicator (5a, 6a);
*c) observe and compare the reaction of metals and non-metals (e.g., carbon, iron, magnesium, sulphur) with oxygen (5a, 6b);

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*See the subsection entitled "Student Activities" on page 6.

d) observe and compare the reaction of metals (e.g., iron, magnesium, zinc) with dilute acids (e.g., hydrochloric acid, sulphuric acid);
e) use molecular model kits to show the structure of simple covalent molecules (e.g., hydrogen, hydrogen chloride, ammonia, water, methane, ethane, propane, butane).

3. Applications

a) Most metals in nature are bonded to other elements and must be removed from their ores in industrial plants.
b) Scrap iron may be used to remove copper from copper solutions by displacement. This technique, however, may not provide adequate purity.

4. Societal Implications

a) Industrial societies are very dependent on metals, and practical methods of separation are needed. Ontario is rich in minerals containing such metals.
b) Some existing methods of handling and storing industrial and chemical wastes may pose a threat to the environment.
c) Acid rain is formed from non-metal oxides emitted as a result of some industrial processes.

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students':
a) laboratory work and organization of experimental data, particularly for student activities 2c and 2d;
b) predictions of the characteristics of elements based on their position in the periodic table;
c) drawings of Lewis structures.

6. Some Safety Considerations

a) When placing alkali and alkaline earth metals in water, students should put a wire screen or a piece of wire gauze on the beaker. They should not attempt to collect the gases released by sodium or potassium.
b) Teachers should ensure that there is adequate ventilation when metals and non-metals are made to react with oxygen.

7. Possible Extensions

Some students might:

a) relate the position of elements in the periodic table to "s" and "p" electron configurations;
b) discuss the formation of double covalent bonds;
c) discuss the formation of isomers;
d) study second and third ionization energies and relate their abnormally high values to the formation of stable ions;
e) report on the lives of scientists such as Lavoisier and Mendeleev.

8. Some Teaching Suggestions

a) When students are classifying elements as metals or non-metals, their attention should be drawn to the location of the elements in the periodic table. They should discuss whether the elements occur in nature as gases, liquids, or solids, and uses of each element should be briefly mentioned.
b) Visual media can be used to reinforce the idea of grouping elements according to their physical and chemical properties and to show how ionization energy is measured experimentally.
c) The usefulness of scientific models should be discussed.
d) Experiments in the following areas can be demonstrated to illustrate the differences among, and the range of properties of, elements: thermal and electrical conductivity of metals and non-metals; hardness and ductility of metals before and after heating and after heating and quenching; reactivity of metals with metallic ions in solution, for example, iron with copper (II) sulphate and copper with iron (III) sulphate.
e) The study of organic chemistry in the OAC will require a knowledge of covalent bonding. A few examples of organic molecules may be introduced briefly in this unit.

Core Unit 3

Gases

Time: 15 hours

Gases were studied intensively even before their existence in the earth's atmosphere was established. Without gases life as we know it would be impossible. The purpose of this unit is to introduce students to the fact that gases reveal extensive information about the nature of matter and to have them investigate some of these relationships quantitatively.

This unit may be divided into topics such as the following:

- ▶ Review of the kinetic molecular theory
- ▶ Molar masses, molar volumes, and the mole
- ▶ Gas laws
- ▶ Problems involving Boyle's and Charles's laws

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the fact that gases play an essential and continual role in daily life (3, 4);
b) a respect for the usefulness of models and theories, such as Boyle's and Charles's laws, that are used to explain natural phenomena (2b).

Skills. Students will have the opportunity to develop skill in:

a) measuring the volume, temperature, and pressure of gases (2a, 2b, 8a);
b) performing experiments to determine the molar masses and molar volumes of gases (2a, 8c);
c) performing an experiment to verify Boyle's or Charles's law (2b);
d) summarizing data in tabular form and interpreting graphs by using data from Boyle's and Charles's laws (2b, 5b, 8d);
e) solving problems involving moles, molar masses and volumes, and Boyle's and Charles's laws (2b, 5c, 8d).

Knowledge. Students will be expected to:

a) recall the main points of the kinetic molecular theory for gases, liquids, and solids;
b) define or indicate the meaning of the following: Boyle's, Charles's, and Dalton's laws; Avogadro's hypothesis; the mole, molar mass, and molar volume (2a, 2b, 8b);
c) define or indicate the meaning of the following terms: absolute zero, Kelvin temperature, standard boiling point, standard temperature and pressure (STP);
d) know the relationship between the Kelvin and Celsius temperature scales.

2. Student Activities

Students are to:

*a) determine molar masses or molar volumes by experimentation (6a, 6b, 8a);
*b) perform an experiment to determine the volume of a given mass of gas (i) at different pressures with the temperature remaining constant *or* (ii) at different temperatures with the pressure remaining constant, and then express the results graphically and mathematically (6a, 6b, 8a).

3. Applications

a) Gases play a role in daily life in numerous ways (e.g., in respiration, weather, hair dryers, vacuum cleaners, soda drinks, baking of cakes, gas furnaces, hot-air heating of residences).
b) An understanding of the compressibility of gases helps explain the workings of such devices as air pumps and aerosol spray cans.
c) Gases are used as a supporting medium in air-supported structures (e.g., domes) and in transportation (e.g., hot-air balloons, dirigibles, tires), and as a means of propulsion (e.g., in the combustion engine, the rocket engine).
d) Gases are essential for human survival (e.g., through their use in scuba and deep-sea diving, oxygen tents, anaesthetics) and for industrial and commercial uses (e.g., in fire extinguishers, refrigeration, heating).
e) Steam is an important gas, which is used in heating and in steam turbines to produce electricity from fossil or nuclear fuels.

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*See the subsection entitled "Student Activities" on page 6.

4. Societal Implications

a) Much of Canada's transportation system depends on the combustion engine.
b) The discovery, recovery, transportation, storage, and distribution of natural gas is a major Canadian industry.
c) The transportation of gases by pipeline, rail car, and cylinder represents a potential hazard to populated areas.

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) laboratory performance and reports;
b) interpretations of graphs by means of data from Boyle's and Charles's laws;
c) solutions of problems.

6. Safety Considerations

a) Large gas cylinders must be secured so that they cannot be knocked over.
b) The gases that are used for student activities should be selected with safety in mind (e.g., carbon dioxide, helium, nitrogen, oxygen). Also, students should be warned of possible hazards when pressures are varied.

7. Possible Extensions

Some students might:

a) conduct experiments to verify Graham's law on gas diffusion rates;
b) be introduced to the ideal gas law: $pV = nRT$.

8. Some Teaching Suggestions

a) Different gases should be used to show that certain properties are common to a variety of gases and that gases exhibit certain regular characteristics. Students should realize that these characteristics are not identical for all gases and do not hold for all temperatures and pressures.
b) The importance of repeatedly examining the behaviour and relationships among many gases before the term *law* can be applied to these relationships should be stressed. Also, the limitations of laws should be emphasized, particularly in regard to the *ideal* gas.
c) As an example of the use of inference in scientific reasoning, students can use Avogadro's hypothesis to infer the diatomic nature of some gas molecules.
d) Computers may be used to plot graphs and to analyse data obtained in experiments and in drills dealing with problems involving Boyle's and Charles's laws.

Core Unit 4

Chemical Reactions

Time: 25 hours

Chemical change is the basis of the study of chemistry. The purpose of this unit is to provide students with opportunities to study chemical reactions, to learn the language of chemistry, and to understand the mole approach to problem solving.

This unit may be divided into topics such as the following:

- ▸ Types of chemical reactions
- ▸ Formulas
- ▸ Amount of substance in moles
- ▸ Chemical equations

Note: In this and subsequent units of study, attention should be drawn to the physical quantity named *amount of substance.* The term *amount of substance* should be properly related to the term *number of moles.* The expression *number of moles* may be used, but students should understand that they are calculating the amount of substance in the same sense that they are calculating the pressure when they determine the "number of pascals" or the temperature when they determine the "number of kelvins". It is proper then, for example, to ask students in a problem to find the pressure or temperature or amount of substance; we rarely ask them to determine the number of pascals or number of kelvins, and therefore, on the basis of parallelism, should rarely ask them to determine the number of moles.

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the wide range of differences among chemical reactions (2a);
b) a curiosity about the atomic theory as it is used to explain chemical reactions and the formation of new substances (3d).

Skills. Students will have the opportunity to develop skill in:

a) identifying types of chemical reactions, such as synthesis, decomposition, single or double displacement, endothermic reactions, exothermic reactions, and simple oxidation (with oxygen only) (2a, 4a, 4b);
b) writing formulas and naming actual binary compounds and compounds containing common ions, such as *anions*, for example, halide, oxide, sulphide, hydroxide, nitrate, chlorate, sulphate, carbonate, and phosphate; and *cations*, for example, ammonium, alkali-metal, alkaline-earth metal, and other metal ions including copper (I), copper (II), iron (II), iron (III), and aluminum (8d);
c) solving problems dealing with the calculation of (a) the amount of substance in moles, given formulas and masses; (b) the number of particles from the amount of substance; (c) the amount of substance in a given volume of gas, given its temperature and pressure; (d) the simplest formula from percentage composition by mass; (e) the molecular formula from simplest formula and molar mass (2b);
d) writing balanced equations for chemical reactions (3a, 8a);
e) measuring mass or volume in experimental work (2b).

Knowledge. Students will be expected to:

a) define or state the meaning of the following: synthesis, decomposition, single or double displacement, endothermic reaction, exothermic reaction, simple oxidation (with oxygen only), mole, Avogadro's constant, binary compound, combining capacity (valence), product, reactant, standard molar gas volume, molar mass;
b) state and use combining capacity (valence) to write formulas with the assistance of the periodic table (8b);
c) describe the difference between molecular and simplest formulas;
d) know the observable characteristics of at least ten substances involved in the reactions studied and state one use for each substance (8c);
e) realize that chemical bonds are involved in the absorbing and releasing of energy.

2. Student Activities

Students are to:

*a) perform different experiments to illustrate at least four of the types of reactions indicated in the objectives, and write balanced chemical equations for these reactions (5a, 6);
*b) perform an experiment to determine the mole ratio for a simple reaction and write a balanced chemical equation for the reaction, for example, magnesium in dilute hydrochloric acid or copper in a silver nitrate solution (5b, 6).

3. Applications

a) The use of word and balanced chemical equations can help students to predict and explain everyday and industrial reactions, such as the rusting of iron.
b) Athletes use hot and cold packs that are heated and cooled by exothermic and endothermic reactions.
c) The chemical composition of common household products indicates the ingredients, and these are often of interest.
d) An understanding of the rearrangement of atoms in molecules has given rise to the production of new synthetic materials.

4. Societal Implications

a) Research continues in the search to make new synthetic materials (e.g., plastics, semiconductors, synthetic blood) for the benefit of society.
b) Society must find safer means of disposing of some of the by-products of large-scale chemical reactions.
c) Common or trade names for substances may not indicate details of their composition; chemical names tend to be more meaningful. The same substance may sell at different prices under different names (8e).

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) observations and records relating to experiments that demonstrate types of chemical reactions in activity 2a;
b) quantitative laboratory work in activity 2b.

6. Some Safety Considerations

Chemicals and reactions should be selected to minimize hazards in the laboratory.

7. Possible Extensions

Some students might:

a) perform a quantitative synthesis (e.g., the production of magnesium oxide);
b) calculate the simplest formula of an organic substance from a combustion analysis of the substance;
c) write formulas using additional elements and ions;
d) balance equations of increased difficulty.

8. Some Teaching Suggestions

a) Examples of reactions studied in previous units can be selected, and students can be required to write balanced chemical equations for such reactions.
b) Computer programs dealing with formulas can be used to help students practise formula writing.
c) Students can list the names and symbols of the elements in the periodic table beyond the first twenty, at the discretion of the teacher.
d) Students can list the names and formulas of substances from the labels of various products in their homes.
e) Different names for the same substance are often seen in drug stores. For example, acetaminophen ($CH_3CONH\text{-}OH$) may be sold under names such as Acetaminophen, Anacin 3, Atasol, Panadol, and Tylenol. Students can compare prices but should be careful to examine similar products (e.g., compare only the 325 mg pills, not "regular" with "extra strength").
f) Reference might be made to the significance of some food additives. Students could discuss the merits of such chemicals (e.g., magnesium phosphate as an additive in non-caking salt and silicon dioxide as an additive in cake mixes).

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*See the subsection entitled "Student Activities" on page 6.

Core Unit 5

Chemical-Reaction Calculations

Time: 13 hours

Substances react chemically in definite proportions by mass. The purpose of this unit is to provide students with opportunities to use balanced chemical equations to calculate the amounts of reactants used and the products formed during chemical reactions.

This unit may be divided into topics such as the following:

- Quantitative relationships from chemical reactions
- Percentage of theoretical yield
- Balanced equations and ratios of amounts of substance (mole ratios)

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a respect for the fact that chemical equations convey all kinds of information about chemical reactions and that such information has been discovered comparatively recently;
b) an appreciation for the fact that the measurements of amounts involved in chemical reactions may involve various methods and play a most important role in science (2).

Skills. Students will have the opportunity to develop skill in:

a) using measuring equipment (balance, graduated cylinder, gas-measuring tube, barometer, thermometer);
b) calculating ratios of amounts of substance in moles (mole ratios) from experimental data to help determine a balanced chemical equation;
c) determining ratios of amounts of substance in moles from balanced chemical equations;
d) calculating mass-mass, mass-volume, and volume-volume relationships from balanced chemical equations;
e) calculating the actual yield as a percentage of theoretical yield from a set of data and a balanced chemical equation (4b, 8c).

Knowledge. Students will be expected to:

a) define the following terms: actual, theoretical, and percentage yield; ratio of amounts of substance in moles (2);
b) analyse the mass and volume relationships represented by balanced chemical equations in terms of reactants and products (2);
c) interpret chemical equations in terms of moles, molecules, ions, and atoms (2).

2. Student Activities

Students may have performed activity 2b in a previous unit and therefore need not repeat it here. Students are to:

*a) conduct an experiment in which a metal reacts with a solution of a metal salt and then calculate the mole ratio and the mass-mass relationship (5a);
*b) conduct an experiment in which a metal reacts with a dilute acid and then determine the mole ratio of metal consumed to hydrogen gas produced and the standard molar volume of hydrogen gas (5a, 6, 8b).

3. Applications

a) Industry uses chemical calculations to determine the amount of raw materials needed to produce various products.
b) The ratio of air to fuel needed for the combustion of such fuels as propane can be calculated, and burners can be designed on the basis of this knowledge.

4. Societal Implications

a) The reaction of different metals in contact with each other can increase corrosion rates. Corrosion of metals is a severe economic problem that has plagued humanity since metals were first processed.
b) Improving the percentage yield of industrial processes may increase profits and decrease the waste of resources. Excess reactants can be recycled, and often are. In addition, new uses can frequently be found for by-products.

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*See the subsection entitled "Student Activities" on page 6.

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) quantitative laboratory work;
b) problem assignments on mole relationships involving amounts of substance stated in moles.

6. Some Safety Considerations

Students should be warned that tall gas-measuring tubes are easily broken. Plastic cylinders or glass ones fitted with rubber collars should be used.

7. Possible Extensions

Some students might devise and conduct an experiment to determine the mass-mass ratio for the reaction of baking soda with citric acid.

8. Some Teaching Suggestions

a) The mole concept can be used in all problem solving.
b) Students can be assigned gas-volume problems at conditions other than standard temperature and pressure prior to doing activity 2b.
c) Students should be informed that a comparison of percentage yields to theoretical yields can be used as evidence that a product is lost in manipulation or that a reaction is incomplete.

Core Unit 6

Solutions

Time: 20 hours

Students deal with chemical solutions every day. They are often unaware of the chemical characteristics of these solutions. The purpose of this unit is to provide students with opportunities to become familiar with a variety of chemical solutions, common units of concentration, methods of handling and preparing solutions, and the carrying-out of an acid-base titration.

This unit may be divided into topics such as the following:

- Water
- Solutions
- Solubility
- Concentration of solutions
- Acids and bases

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a commitment to investigate the properties of solutes and solutions found in everyday life in order to use them wisely and safely (2e, 3b, 4a, 4b, 8d);
b) an appreciation of water as a widely used solvent that is essential for all life (2c, 8a).

Skills. Students will have the opportunity to develop skill in:

a) collecting and interpreting qualitative and quantitative data from experiments involving chemical solutions (2a, 2b, 2d, 2f);
b) using volumetric equipment such as graduated cylinders, pipettes, burettes, and volumetric flasks (2b, 2e);
c) interpreting and graphing solubility data (2d, 3f);

d) solving problems involving concentration units and data such as moles per litre and percentage by mass (2b, 2d, 2e, 3a, 8b);
e) performing acid-base neutralization reactions and an acid-base titration (2b);
f) solving problems involving the neutralization of acids and bases (2b);
g) preparing chemical solutions accurately (2b, 2d);
h) solving problems involving concentrations of acids, using density and percentage composition by mass;
i) using solubility rules and charts to assist in the separation and identification of unknown ions (2f);
j) writing net ionic chemical equations (2a);
k) identifying types of chemical reactions as acid-base or precipitation reactions (2a).

Knowledge. Students will be expected to:

a) describe the importance of water as a solvent (2c, 3c, 3e, 4a, 4c);
b) define or explain the meaning of the following: acid, base, neutralization, pH, solute, solvent, high and low solubility, strong and weak electrolytes, hydrated ions;
c) explain and give examples of the following: solubility, acid-base neutralization, ionic and net ionic equations, spectator ions, precipitation;
d) use qualitative solubility rules for representative ions in Groups I, II, and IV-VII and list some ions that tend to form insoluble salts (2a).

2. Student Activities

Students are to:

*a) investigate general reactions involving the formation of precipitates;
*b) use an acid of known concentration to carry out a quantitative titration of a base with unknown concentration;
c) perform experiments to illustrate some of the distinctive properties of water and prepare saturated and unsaturated solutions with at least one solution to be supersaturated and tested by the seed-crystal test;
d) calculate and prepare quantitatively various concentrations of solutions (e.g., bluestone in water) with one concentration to be checked by visual colourimetry (8b);
e) prepare various dilutions of common household and laboratory acids and bases and check the pH of the resulting solutions;
*f) determine experimentally the identity of an "unknown" ion (e.g., a chloride, sulphate, or hydroxide) using a simple qualitative test.

3. Applications

a) Different concentration units are used depending on the concentration and type of product being considered.
b) A knowledge of the conductivity of tap water explains why it is dangerous to use electrical appliances in wet areas.
c) Acids and bases are used in the preparation of foods (e.g., cola, cheese), cleaning materials, and other important products.
d) Antifreeze-and-water solutions have lower freezing points than does either pure ethylene glycol or water on its own.
e) Calculations of concentrations of solutions are important in the preparation of drugs and home-cleaning chemicals and in industrial refining and processing.
f) Solubility data provide the means of separating some ores to obtain metals or non-metals.

4. Societal Implications

a) Finding good drinking water is difficult, since ground water often contains many contaminants (8a).
b) Because water is essential to human survival, it is important to know the types and quantities of the dissolved materials in it and how it may be purified (8a).
c) The proper dilution or neutralization of hazardous solutions can prevent accidents.
d) The mixing of certain acids and bases may be hazardous; for example, when alkaline chlorine bleach is mixed with some acidic toilet-bowl cleaners, poisonous chlorine gas is released.
e) Acid rain and its effect on the environment have become the focus of many discussions and studies.
f) Acids and bases can be used for such familiar products as stomach antacids and for etching metal products.

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students':

a) ability to determine accurately the concentration of the unknown base in activity 2b;
b) identification of an unknown ion in activity 2f;
c) reports on laboratory work.

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* See the subsection entitled "Student Activities" on page 6.

6. Safety Considerations

a) When selecting student activities, teachers must pay special attention to the choice of chemicals in order to ensure safety.
b) The use of acids and bases requires extra care because of their unique characteristics.

7. Possible Extensions

Some students might:

a) discuss bonding in the three states of water;
b) explore the activity series of metals that displace H^+ in solution;
c) extract dyes from leaves or plants to produce acid or base indicators other than litmus;
d) explore the effect of dissolved materials on the properties of a solvent (e.g., boiling-point elevation, freezing-point depression);
e) use a pH meter or a colourimeter to perform an instrumental analysis;
f) perform a titration of an antacid;
g) develop a systematic scheme (flow chart) for qualitative analysis (8c).

8. Some Teaching Suggestions

a) Facts about the nature of water can be related to things that students might see or know (e.g., the fact that water expands as it is cooled from 4°C to 0°C and, hence, lake water freezes from the top down rather than from the bottom up). Local problems with water purity can be discussed as well.
b) Students can be required to make solutions after doing calculations (e.g., prepare a standard acid or base or a saturated solution).
c) If a systematic flow chart is developed for qualitative analysis (see possible extension 7g), the process of thinking through qualitative schemes should be stressed. Examples that can be turned into a flow chart should be provided. If students have access to a computer, they should be encouraged to develop a program from a solubility chart.
d) When dealing with societal implications in this unit, the teacher can have students discuss the role of chemists in the production and use of chemicals in relation to societal expectations about chemical usage and control. For example, the question of the fluoridation of drinking water has produced lively debate.

Core Unit 7

Industry and Society

Time: 9 hours

Many of the products required by modern society are produced by chemical industries through the application of science and technology. While many benefits result from these products, the byproducts produced in the chemical processes may cause environmental problems. The control of these problems involves an understanding of science and technology balanced by the needs of our society.

The purpose of this unit is to provide students with opportunities to consider their responsibilities as citizens in a technological society, to acquire some of the scientific and technological knowledge that they will need in order to make informed decisions, and to understand the role played by a particular chemical industry as it supplies products to satisfy the demands of society.

Many different chemical industries could be studied effectively to fulfil the objectives of this unit. Appropriate examples could be the pharmaceutical industry, the petrochemical industry, the pulp-and-paper industry, or the steel industry. It is intended that students achieve the objectives of this unit by selecting, in consultation with the teacher, a particular industry for study.

This unit may be divided into topics such as the following:

- Chemicals produced by an industrial society
- Factors affecting a selected chemical industry
- Location and environmental concerns
- Human resources

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the way in which science and technology affect their daily lives (3a, 4b, 4e);
b) a commitment to be knowledgeable about the scientific process in order to help society make informed decisions affecting scientific development (4b-4e, 8b-8f);
c) an appreciation for the value component that goes into decisions involving science and technology in society (4b-4e, 8c-8f);
d) a concern for the need of developing countries to have access to technological expertise from developed countries such as Canada (4e, 8d, 8e);
e) a respect for the role of scientific research and development in industry (4c, 8d-8f);
f) a commitment to the wise use of the earth's finite resources (3b, 4b, 4d, 4e, 8d, 8e).

Skills. Students will have the opportunity to develop skill in:

a) conducting simple experiments related to the chemical industry under study (2a, 5a, 8a);
b) gathering data from various sources (5c);
c) organizing data to produce a formal report (2b, 5c);
d) making decisions (2).

Knowledge. Students will be expected to:

a) state the names, formulas, properties, and uses of five important industrial chemicals and five common household chemicals;
b) explain the difference between resources and reserves and explain how natural resources generate wealth for a nation (4b, 5b, 8d-8f);
c) discuss some of the necessary steps in the progression from research to plant production in the industry under study, for example, engineering design, product testing, and pilot projects (4a, 4c, 5b, 8c-8f);
d) describe the factors that were likely considered in the establishment of the industrial plant being studied, for example, sources and transportation of raw materials, energy requirements, human resources, market accessibility, waste disposal, environmental problems, efforts to deal with environmental problems, and economic considerations (5b);
e) explain the difference between science and technology and their interdependence in the industry being studied (4c, 5b, 8d, 8e);
f) discuss the role of research in helping the industry under study to remain competitive in the world market (4c, 5b, 8d-8f).

2. Student Activities

Students are to:

*a) perform two or three simple experiments to illustrate the physical or chemical properties of some industrial chemicals, including, where feasible and safe, chemicals used or produced in the industry being considered (5a, 8a);
*b) prepare a formal report on the industry under study, including all of the items relating to the industry that are outlined in the knowledge objectives above (5c).

3. Applications

a) Chemicals and products resulting from chemical processes are used by students in their homes, the school, and the community. Some of these might be related to the industry under study.
b) Chemicals are used in large quantities in industrialized societies.

4. Societal Implications

a) The production of chemicals and the development of products by means of chemical processes provide many kinds of employment opportunities.
b) Canada possesses abundant natural resources, which have allowed it to achieve a high standard of living. Chemical industries based on these resources have played a major role in creating the nation's wealth.
c) Much of the success of any nation's chemical industry depends on its being innovative in science and technology. Intensive research and development by the chemical industry can help Canada remain competitive in the international marketplace.
d) Citizens receive the benefits from chemical industries and, accordingly, must share the responsibility for helping to diminish the accompanying social and environmental problems.
e) The benefits of industrial development are often accompanied by social disruption and environmental problems, particularly in developing countries.

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* See the subsection entitled "Student Activities" on page 6.

5. Evaluation of Student Achievement

At least 60 per cent of the term mark for this unit is to be based on students':

a) laboratory work;
b) participation in classroom discussions;
c) formal reports described in activity 2b.

6. Safety Considerations

Chemicals and reactions should be selected to minimize hazards in the laboratory.

7. Possible Extensions

Some students might:

a) examine some relationships among important chemical industries (e.g., the petroleum and petrochemical industries);
b) examine other industries that illustrate the ideas stressed in this unit (if possible, local industries should be chosen);
c) discuss the environmental problems associated with industrialization;
d) discuss the responsibility of chemical industries towards developing countries.

8. Some Teaching Suggestions

a) The following are some experiments that can be used in conjunction with the different chemical industries that may be selected:

   Pharmaceutical industry. Students can test the effectiveness of some commercial antacids. They can also test the rate at which various tablets dissolve.

   Petrochemical industry. Students can test different plastics (e.g., styrofoam) for heat conductivity and tensile strength. They can also produce acetylene (the precursor of many monomers) from calcium carbide.

   Pulp-and-paper industry. Students can test different characteristics of paper. They can also produce different kinds of paper.

   Steel industry. Students can conduct experiments that deal with the physical and chemical properties of iron. They can also conduct experiments to determine different physical properties of cast iron and various types of steel.

b) The stages in the manufacture of an item produced by the chemical industry (e.g., a "tin" can, a plastic bottle, a styrofoam cup) can be traced.
c) Students can take a field trip to a chemical industry discussed in the unit or to any suitable local industry. They can discuss why the industry was established in its present location and whether it would be established in the same place if a site were being chosen today.
d) Open-ended discussions can be conducted on what chemical industries are needed by society and on the nature of citizens' responsibilities to the environment, to each other, and to the global community. The differences among facts, attitudes, values, and moral responsibilities should be stressed.
e) A decision-making simulation exercise involving a hypothetical country that contains exploitable raw materials can be conducted. Scientific, technical, geographic, social, and economic factors should be taken into account in the exercise.
f) Students can discuss how the money allocated for research and development often depends on decisions made by government and industry as well as by scientists. The fact that such decisions can be influenced by all citizens should be stressed.
g) Planning for this unit should be done in conjunction with the teacher in the school's library resource centre. Advance notice should be given so that relevant sources of information may be identified and reserved for student use.

Chemistry, OAC
(SCHOA)

Core Units

Organic Chemistry
Atomic Structure and
Molecular Architecture
Energy and Rates in
Chemical Reactions
Equilibrium – Introduction
Equilibrium – Applications
Redox and Electrochemistry
Independent Investigation

(110 hours)

Core Unit 1

Organic Chemistry

Time: 15 hours

Organic chemistry helps explain living systems and the environment. The purpose of this unit is to provide students with opportunities to learn organic formulas and nomenclature, to become familiar with the properties of organic compounds, to study organic reactions, and to learn the fundamentals of organic chemistry that are necessary for an introduction to the study of biochemistry.

This unit may be divided into topics such as the following:

- Hydrocarbons
- Functional groups
- Hydrogenation, halogenation, oxidation, and dehydration
- Polymerization
- Aromatic compounds
- Properties and uses of organic compounds

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the large number of organic compounds and their importance in daily life and industry (3, 8c, 8d);
b) a realization that chemicals include those that are of great benefit to society and also those that can be extremely dangerous (3, 4, 6d, 6e).

Skills. Students will have the opportunity to develop skill in:

a) naming simple organic compounds from structural formulas, primarily by the International Union of Pure and Applied Chemistry (IUPAC) method (5b, 8d);
b) writing simple organic formulas from organic names (5b, 8b);
c) identifying simple compounds by names other than IUPAC names (5b);
d) recognizing some functional groups and their importance as reaction sites;
e) using molecular formulas to determine the number and structure of isomers (2c);
f) using chemical tests to identify saturated and unsaturated hydrocarbons (2a);
g) measuring heats of combustion (2f).

Knowledge. Students will be expected to:

a) define the following: organic and inorganic substances, isomers, polymers, monomers, addition and condensation polymerization, aromatic compound, hydrogenation, halogenation, dehydration;
b) name (using the IUPAC system) carbon chains and branches of up to ten carbon atoms of alkanes, alkenes, and alkynes;
c) draw structural formulas of hydrocarbon molecules having one, two, or three carbon atoms (5b);
d) name and draw structural formulas of common organic functional groups, for example, alcohols, aldehydes, ketones, acids, esters, amines, and simple aromatics (3b, 5b);
e) identify substitution and addition reactions from the formulas of reactants and products (5b);
f) relate oxidation and reduction to loss or gain of hydrogen or oxygen;
g) be aware of the general physical and chemical properties and uses of representative samples of the various organic series studied;
h) identify organic molecules as a source of energy in fossil fuels, biomass fuels, and biochemical reactions (2f, 3g, 4f).

2. Student Activities

Students are to:

*a) test for unsaturated hydrocarbons using alkaline potassium permanganate or bromine water (6a, 6b);
b) collect and prepare samples of acetylene and conduct experiments to study its properties (6a, 8e);
*c) examine and compare the properties of two organic isomers (6a, 6b);
d) select appropriate reactants, such as ethanol and butanoic acid, and synthesize a specific ester (3d, 6a-6c);
e) prepare a condensation polymer (4e, 6d);
*f) measure and compare the heats of combustion produced by ethanol and paraffin (candle) wax.

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* See the subsection entitled "Student Activities" on page 6.

3. Applications

a) Hydrocarbons are used as fuels. Gasoline is a mixture of hydrocarbons.
b) The benzene ring is part of the structure of many compounds. Lacquer thinner is made from toluene.
c) Ethanol is contained in all alcoholic beverages. Acetone is also used in plastic cements and in resin solvents. Formaldehyde solution is sometimes used as a biological preservative and is used in polymer formation.
d) Esters are added to foods to create aroma and taste.
e) Such common products as polyethylene, PVC, polystyrene, Teflon, and synthetic rubber are addition polymers.
f) Vegetable oils are saturated by hydrogenation to produce fats that can be used as substitutes for dairy products.
g) Compounds of carbon (e.g., proteins and carbohydrates) play a dominant role in the chemistry of living things.
h) Organic chemists play a key role in synthesizing numerous pharmaceuticals.

4. Societal Implications

a) Modern society depends on the industrial production of organic chemicals as food supplements, pharmaceuticals, agricultural chemicals, automotive parts, fabrics, dyes, and cosmetics, many of which are made in Canada. Highly trained professionals must conduct extensive research to discover, test, and produce new, much-needed organic chemicals.
b) Many organic compounds have toxic effects. For example, benzene and formaldehyde are carcinogenic. Ethanol and methanol have harmful but quite different physiological effects on humans. Some chlorinated products (e.g., DDT, PCBs) are poisonous and pose a hazard to the environment. The challenge is to find substitutes for such substances.
c) The addition of tetraethyl lead to gasoline improves engine performance, but it raises environmental considerations.
d) The use of artificial rather than natural flavouring agents in foods causes allergic reactions in some people.
e) Many polymers are resistant to natural decomposition, and thus their production creates waste-disposal problems.
f) Alternative sources for energy must be devised and developed in order to conserve petroleum and natural gas.
g) Pharmaceuticals are used to relieve human suffering. The use of these materials must be controlled, however, because, while they have benefits, they may also have side effects (e.g., aspirin).
h) As a result of chemistry, countless organic substances have benefited modern society.

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) laboratory reports;
b) work involving chemical names and formulas.

6. Safety Considerations

a) Organic compounds should be kept away from flames. Good ventilation is necessary when gases and volatile liquids are used.
b) Separate disposal containers should be provided for organic wastes.
c) The usual precautions should be observed when concentrated sulphuric acid is used and when fuels are burned. Reaction mixtures of alcohols and organic acids should be heated in boiling water. Care should be taken with open flames.
d) Polymers should be prepared in a fume hood.
e) Students should be warned that many halogenated hydrocarbons are toxic.

7. Possible Extensions

Some students might:

a) distil tar sands using steam;
b) use models to study the structure of some simple molecules;
c) draw structural formulas for isomers of C_6H_{14}, C_6H_{12}, and C_6H_{10} and study cis- and trans-isomers;
d) prepare a soap or detergent;
e) synthesize, purify, and do a purity check of an organic compound, such as aspirin or benzoic acid;
f) demonstrate the synthesis of nylon 66;
g) compare the thermosetting of polymers, thermoplastics, and elastomers.

8. Some Teaching Suggestions

a) Where possible, models should be used throughout this unit to illustrate the concepts discussed.
b) Chemical bonding, Lewis diagrams, and structural formulas should be reviewed.
c) The reasons for the existence of so large a number of organic compounds should be discussed.

d) From a variety of labels from various home products and foods, students can identify a great number of organic compounds (attempting to write formulas for the various ingredients) and indicate the probable reason for their presence in the product.
e) It is of historical interest to note that acetylene was first produced on a large scale in Canada. Kerosene was also first developed in Canada. The first commercial oil well was located in Oil Springs, Ontario. Some students might find further details about these points and report on them to the class.

Core Unit 2

Atomic Structure and Molecular Architecture

Time: 13 hours

The environment consists of gases, liquids, and solids. The study of gases reveals the types of bonds within molecules, while the study of liquids and solids helps us understand interactions between molecules or ionic solids. The purpose of this unit is to provide students with opportunities to review bonding in the gaseous state and to examine the different types of forces that hold liquids and solids together.

This unit may be divided into topics such as the following:

- Properties of substances
- Bonding in liquids, solids, and gases
- Atomic structure
- Molecular structure

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an ability to accept changes in scientific theories as illustrated by the evolution of the atomic theory over the years (8b);
b) an appreciation of the fact that the properties of gases, liquids, and solids can be partly explained and predicted by scientific theories (2a, 5a, 8a);
c) an appreciation of the concept that substances are held together by both intermolecular and intramolecular forces.

Skills. Students will have the opportunity to develop skill in:

a) identifying the conditions that make a bond predominantly covalent or ionic (2);
b) using ionization energies or electronegativities to identify polar molecules;

c) using the periodic table to predict which elements are likely to form network solids or molecular solids (2b, 3a);
d) predicting the shape or structure of simple molecules by means of a bonding theory such as the VSEPR (valence-shell electron-pair repulsion) theory (2a).

Knowledge. Students will be expected to:

a) list some observed properties of elements and compounds where the elements are representatives of various groups in the periodic table (2, 8a, 8c);
b) explain the properties of substances in terms of the following: (i) Van der Waals forces, (ii) dipole forces, (iii) ionic bonds, (iv) metallic bonds, (v) hydrogen bonds (5b);
c) explain the excellent solvent properties of water in terms of its polarity (2b, 8d);
d) recognize and explain which elements in the periodic table form liquids or solids held together predominantly by Van der Waals forces (2a, 3d);
e) describe the shape and bonding in two- and three-dimensional network solids and relate this bonding to each solid's hardness and electrical conductivity (3a-3c, 3e, 4a, 5b);
f) define or explain the meaning of the following: polar and non-polar molecules, Van der Waals forces, network solids, molecular solids, bonding in metals, bonding in solids, hydrogen bonding;
g) indicate the relative strengths of bonding forces;
h) outline the evolution of the atomic theory from Aristotle to the quantum-mechanical view;
i) differentiate between the Bohr-Rutherford view of the atom and the quantum-mechanical view of the atom;
j) write out electron configurations (e.g., $1s^2 2s^2 2p^1$) for the first twenty elements and indicate such configurations by means of schematic orbital diagrams;
k) identify the bonding orbitals and molecular shape for the second-row hydride and fluoride molecules (2a);
l) relate metallic bonding to orbital occupancy and ionization energy (5b);
m) describe the differences and similarities between metallic and ionic bonding (2b, 5b).

2. Student Activities

Students are to:

*a) conduct experiments to examine and compare the properties of liquids and solids that can be explained by the various types of bonding (3a, 3b, 8a);
*b) draw structural formulas and build three-dimensional models of covalent molecules (8d).

3. Applications

a) The hardness of diamond, which is used for drilling bits, is partially explained by its three-dimensional network structure. Industrial diamonds may be made by subjecting carbon to a high temperature and pressure, usually in the presence of a catalyst.
b) Graphite is a two-dimensional network solid that is used as a dry lubricant in machines subjected to high temperatures because it is soft and slippery.
c) The physical properties of metals change dramatically when impurities are introduced. For example, carbon in steel makes steel more brittle and less ductile because the slippage of planes is affected.
d) Some substances whose molecules are held one to another only by Van der Waals forces (e.g., dry ice, liquid helium) have low melting points and thus are excellent low-temperature refrigerants.
e) Traces of impurities can affect electrical conductivity. For example, traces of arsenic in silicon make silicon a semiconductor.

4. Societal Implications

a) An understanding of molecular structure led to the development of semiconductors and other materials with the properties needed for the development of computers and other electronic devices.
b) Molecular structure has helped organic chemists to determine the shapes of some simple and complex molecules (e.g., alcohols, DNA, RNA), which in turn has led to advances in genetic engineering.

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) observations and explanations in their laboratory reports for activity 2a;
b) brief oral or written reports dealing with a specific aspect of bonding (e.g., an amplification of one of the objectives or an item from the "Applications", "Societal Implications", or "Possible Extensions" mentioned in this unit of study).

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* See the subsection entitled "Student Activities" on page 6.

6. Safety Considerations

The safety precautions necessary for this unit will depend on the reactions selected for activity 2a.

7. Possible Extensions

Some students might:

a) investigate the concept of hybridization;
b) study the crystal structure of metals in relation to bonding;
c) discuss the anomalies exhibited by water;
d) examine the role of nuclear magnetic resonance, infrared spectroscopy, and X-ray diffraction in seeking further to explain the structure of substances;
e) discuss d and f orbitals.

8. Some Teaching Suggestions

a) The relationship between the observed properties of substances and the postulated types of bonding should be stressed in order to explain the chemical properties.
b) The usefulness and limitations of scientific theories and models should be emphasized.
c) All orbital occupancy and structural work with elements should be related to the positions of the elements in the periodic table.
d) Films can be shown to illustrate bond polarity, the structure of crystals, and the process of molecular spectroscopy.

Core Unit 3

Energy and Rates in Chemical Reactions

Time: 20 hours

All chemical reactions are associated with energy changes. The purpose of this unit is to provide students with opportunities to determine the heats of reactions and to understand how various factors affect reaction rates.

This unit may be divided into topics such as the following:

- Enthalpy
- Conservation of energy and the additivity of heats of reaction
- Physical, chemical, and nuclear energy
- Rates of reaction
- Collision theory and activation-energy diagrams
- Nuclear reactions

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the fact that energy change is one of the more important features of all chemical reactions;
b) a respect for the fact that industrial, environmental, and biological reactions occur at specific rates that are determined and controlled by an identifiable set of factors (3a, 3b, 4c).

Skills. Students will have the opportunity to develop skill in:

a) using the following measuring equipment: thermometers, graduated cylinders, balances;
b) calculating the heat of reaction from a set of calorimetric data (2a);

c) calculating the heat of reaction and the amounts of substance involved, using relationships involving a balanced chemical equation (5b, 8);
d) calculating the heat of reaction by summation, given appropriate equations and their heats of reaction (4a, 4b, 5b);
e) calculating the heat of reaction using standard heat-of-formation tables (5b);
f) interpreting data from graphs of temperature or concentration versus time of reaction (2b, 5c).

Knowledge. Students will be expected to:

a) define or state the meaning of the following: energy (exothermic, endothermic, enthalpy); change of enthalpy or heat of reaction; Hess's law (an example of the law of conservation of energy); standard heat of formation; translation, vibrational, and rotational molecular motions; molecular enthalpy; molar enthalpy; reaction rate; reaction mechanism; activation energy; activated complex; rate-determining step; catalyst;
b) explain the storage of energy by molecules in terms of potential and kinetic energy (3a, 3c);
c) relate the heat of reaction to the change in enthalpy as the reactants are converted into products in a chemical reaction (2a);
d) explain, on the basis of the collision theory, how various factors create differences in reaction rates (2b);
e) compare the magnitudes of the energy involved in physical, chemical, and nuclear changes (3c, 4d);
f) interpret potential-energy diagrams (5b);
g) compare fission and fusion reactions (3c);
h) balance simple nuclear equations (5b).

2. Student Activities

Students are to:

*a) conduct an experiment to illustrate Hess's law, for example, the reaction between sodium hydroxide and hydrochloric acid;
*b) determine the effect of temperature, concentration, and catalysis on reaction rates (5c).

3. Applications

a) Energy is released slowly from food; quickly, but in a controlled manner, from fuels; and at an uncontrolled, rapid rate from explosives. Applications of chemical reactions often depend on the rate of energy release.
b) Catalysts are used in many industrial processes (e.g., the Haber process) in order to increase the rate of product formation.
c) Nuclear reactions produced through the CANDU reactor provide a significant proportion of our electrical energy.
d) Through electrolysis, hydrogen can be used as a means of storing energy from another source in a form that is more easily transported. Coal gasification is useful for similar reasons.
e) Career opportunities are available for chemists and chemical engineers in the area of thermochemistry and chemical kinetics.

4. Societal Implications

a) The process of coal gasification requires energy input. The amount of energy required must be taken into account in calculating the net energy available in the final fuel.
b) Although the heats of reaction can be theoretically calculated, not all of this energy is actually available, because some is always lost during conversion.
c) Although the octane rating of gasoline can be increased by introducing additives (e.g., lead tetraethyl) in order to alter the rate at which combustion takes place, environmental concerns need to be considered.
d) The production of electrical energy from nuclear reactions has both positive and negative implications.

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students':

a) laboratory reports and performance;
b) problem assignments;
c) interpretations of graphical data.

6. Safety Considerations

The safety precautions that are required will depend on the reactions selected by the teacher.

7. Possible Extensions

Some students might:

a) discuss heats of reactions in terms of bond-dissociation energies;
b) investigate the enzymes that are active in various biochemical systems;
c) investigate the use of inhibitors in chemical reactions.

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* See the subsection entitled "Student Activities" on page 6.

8. Some Teaching Suggestions

a) The practical or normal unit for expressing quantities of energy in this course is the kilojoule. In calculations involving other physical quantities, such as pressure, volume, and amount of substance, quantities of energy should be expressed in joules.
b) This and forthcoming units should be used to illustrate unit analysis. Students should be able to show that the SI units on the right side of an equation exactly match those on the left side.

Core Unit 4

Equilibrium – Introduction

Time: 12 hours

A quantitative approach to the study of chemistry must include the study of chemical equilibrium. While this unit introduces the topic of equilibrium with a consideration of the gaseous phase, aqueous solutions will be emphasized later in the course. The purpose of this unit is to provide students with opportunities to analyse the principles of equilibrium systems and to solve problems involving the law of chemical equilibrium.

This unit may be divided into topics such as the following:

- ▸ Equilibrium – dynamic nature
- ▸ Equilibrium systems – Le Chatelier's principle
- ▸ Equilibrium systems – quantitative aspects

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation that theories and principles can help to explain chemical equilibrium (4);
b) a curiosity in examining the factors that determine the state of equilibrium for various systems (2a, 2b).

Skills. Students will have the opportunity to develop skill in:

a) predicting the results of experiments (2a, 2b, 2d);
b) organizing data from experiments (2a, 2b);
c) making generalizations from a set of data (2a, 2b);
d) recognizing a system that is in equilibrium and applying the principles involved to other systems (2b);
e) solving qualitative problems involving Le Chatelier's principle (5b);
f) solving qualitative and quantitative problems involving equilibrium constants K_c (5b).

Knowledge. Students will be expected to:

a) define or state the meaning of the following: Le Chatelier's principle, homogeneous system, heterogeneous system, closed system, law of chemical equilibrium, dynamic equilibrium, entropy;
b) list the conditions that are necessary for chemical equilibrium (2a);
c) state Le Chatelier's principle and apply it to systems at equilibrium (5b, 8b);
d) define and use the equilibrium constant (5b, 8b);
e) discuss the tendency of reactions to achieve minimum energy and maximum entropy (8a).

2. Student Activities

Students are to:

*a) establish the conditions for equilibrium and the dynamic nature of equilibrium by observing the effect of temperature or concentration on a system in equilibrium (3b, 8c);
b) demonstrate the effects of pressure and temperature changes on a typical equilibrium system, such as $H_2O_{(l)} \rightleftharpoons H_2O_{(g)}$ (3b);
c) demonstrate closed and open systems (3a, 3b);
d) show that reactions in a system go to completion when products are removed from the system.

3. Applications

a) An understanding of equilibrium helps to explain how the oceans help control the amount of carbon dioxide in the atmosphere and why soft drinks lose their effervescence when the cap is removed.
b) Equilibrium principles are applied in industrial processes (e.g., in the Haber process for producing ammonia) to increase reaction rates and product yields.

4. Societal Implications

The application of our knowledge of equilibrium principles makes possible the economical large-scale industrial production of chemicals. A number of examples from local industries might be mentioned.

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) records of laboratory work;
b) problem assignments.

6. Safety Considerations

The precautions required in this unit will depend on the reactions selected in the activities.

7. Possible Extensions

Some students might:

a) examine data on pressure and temperature for a commercial process such as the Haber process for producing ammonia and determine the optimum conditions for the production of the substance;
b) determine experimentally the value of an equilibrium constant.

8. Some Teaching Suggestions

a) The concept of entropy should be dealt with briefly.
b) Any quantitative discussion of rate laws should be avoided in the establishing of the equilibrium constant.
c) The equilibrium $Fe^{3+}_{(aq)} + SCN^{-}_{(aq)} \rightleftharpoons FeSCN^{2+}_{(aq)}$ should be examined through student experiment or through a teacher demonstration and an ensuing discussion.

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* See the subsection entitled "Student Activities" on page 6.

Core Unit 5

Equilibrium – Applications

Time: 18 hours

This unit is a logical continuation of unit 4. The purpose of this unit is to provide students with opportunities to examine equilibrium as it applies to the solubility-product constant and to acid and base reactions.

This unit may be divided into topics such as the following:

- ▶ Solubility equilibrium: K_{sp} expressions
- ▶ Aqueous acids and bases
- ▶ Neutralization

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the fact that a high degree of precision is involved in chemical analysis (2a, 2c-2e);
b) a questioning and critical approach towards the several viable definitions for acids and bases.

Skills. Students will have the opportunity to develop skill in:

a) organizing data from experiments (2a, 2c-2e);
b) diluting solutions (2a, 2d);
c) solving quantitative problems involving pH and various equilibrium constants K_{sp}, K_a, K_w (2a, 2d, 2e, 5b);
d) choosing indicators for acid-base titrations (2c-2e).

Knowledge. Students will be expected to:

a) define or explain the meaning of the following: solubility product; salt; electrolyte; acid-base indicator; neutralization; hydrolysis of salts; acids and bases according to Arrhenius, Bronsted-Lowry, and Lewis;
b) explain the significance of the equilibrium $HOH_{(l)} \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)}$;
c) define and use the following terms: K_{sp}, K_a, K_w, pH (2a, 2d, 2e);
d) review titration techniques in determining the concentrations of unknown acid and base solutions;
e) describe a procedure to determine the pH of common household chemicals and foods (3b);
f) explain why the pH of some salt solutions is other than 7 and test the explanation with other salt solutions;
g) compare the reliability of the use of qualitative solubility rules and K_{sp} values as a means of predicting precipitate formation.

2. Student Activities

Students are to:

*a) determine a K_{sp} value by experiment;
b) determine by experiment the effect of changes in $[H^+]$ and $[OH^-]$ on an appropriate equilibrium system;
c) calculate changes in pH during titrations and plot a graph showing pH versus volume for the acid or base used;
d) determine by experiment the K_a value for a weak acid, using indicators or a pH meter;
e) standardize an acid or a base, using primary standards (2c).

3. Applications

a) Knowledge of acid-base chemistry fosters an understanding of acid rain and the means of rectifying the problem.
b) Quantitative acid-base analysis is used in the quality control of products for which the pH is important to product performance.
c) Correct pH control of swimming pools is required to ensure water quality.

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* See the subsection entitled "Student Activities" on page 6.

4. Societal Implications

a) A better understanding of the acid-base chemistry of the human body leads to improved medical techniques as well as to improved foods, drugs, and cosmetics.
b) Scientists understand much of the chemistry of acid rain, but rectifying the problem involves value judgements. Many marble and limestone structures, as well as forests and lakes, are being affected by acid rain.

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) records of laboratory work;
b) laboratory results from activity 2a.

6. Safety Considerations

Students should use protective eyewear when working with acids and bases.

7. Possible Extensions

Some students might:

a) using K values, analyse for the presence of metal ions;
b) conduct experiments to determine and compare the heats of reaction for several different neutralization reactions.

8. Some Teaching Suggestions

The extensions in this unit should focus on additional laboratory work rather than on mathematical problem solving.

Core Unit 6

Redox and Electrochemistry

Time: 20 hours

Electrochemistry has many applications in daily life. The purpose of this unit is to provide students with opportunities to understand the terminology of electrochemistry and its applications and to understand how results can be predicted from theory.

This unit may be divided into topics such as the following:

- Electrochemical terminology
- Half-cell reactions and standard E^0 values
- Predicting redox reactions
- Oxidation numbers
- Electrolytic processes
- Balancing redox equations and quantitative relationships
- Societal implications of redox reactions

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a curiosity about the prevalence of redox reactions in everyday life (4a, 4b);
b) a commitment to continue to develop the manual laboratory skills that are essential for obtaining quantitative results in scientific investigations (2a, 2b).

Skills. Students have the opportunity to develop skill in:

a) constructing electrochemical cells and measuring the voltages produced (2a, 5a);
b) using experimental data to rank oxidizing and reducing agents in order of their relative strengths (2a);
c) constructing electrolytic cells (2a, 2b);
d) balancing chemical equations using half reactions;

e) predicting the spontaneity of redox reactions using half-cell potentials (2a);
f) estimating the minimum voltage required to perform various electroplating experiments.

Knowledge. Students will be expected to:

a) define the following redox terms: oxidation, reduction, oxidizing agent, reducing agent, oxidation state, oxidation number, spontaneity, voltage, redox, anode, cathode, electrolytes, electrolysis, electrochemical reaction, electron flow, half-cell, salt bridge, electrochemical cell, electrolytic cell;
b) state the meaning of, and rules for determining, oxidation numbers;
c) balance redox reactions for mass and charge, given the half-cell reactions used;
d) describe the processes that occur when electrical current is applied to produce chemical reactions (2b, 2c);
e) list commercial applications of electrochemical cells and electrolysis (2c);
f) list the conditions necessary for corrosion to occur and explain methods of preventing it from happening (3b).

2. Student Activities

Students are to:

*a) prepare electrochemical cells, including one that uses a salt bridge, and record their voltages (6, 8a-8d);
*b) prepare a simple electrolytic cell and examine the results of electroplating (3d, 4a, 6a, 6d);
*c) prepare a report on the industrial production by electrolysis of a particular substance and indicate the benefits and hazards posed by the manufacture of this particular material (3e, 3f, 4b, 4c, 5b).

3. Applications

a) The spontaneous redox reactions that occur in a battery provide useful energy.
b) The prevention of the corrosion of metals (e.g., in automobiles and eavestroughs) is an example of the beneficial use of redox reactions.
c) Electric cars are powered by the energy from redox reactions.
d) The electrolytic refining of metals, electroplating in general, and the removal of metals from ores are common industrial processes. They require energy because these processes reverse the spontaneous redox reactions.
e) In some situations, supplies of Group I and Group VII elements are most easily obtained by electrolysis.
f) Pure water may be obtained from salt water by means of the process of electrodialysis.

4. Societal Implications

a) Electrolytic processes (e.g., electroplating; production of aluminum, magnesium, and sodium; refining of copper; synthesis of sodium hydroxide and sodium hypochlorite) supply many very useful products to serve our needs.
b) Electrolysis is used in some of Canada's major industries to obtain specially desired metals from ores (e.g., magnesium and aluminum alloys for aircraft, titanium and other rare metals for spacecraft, metals for artificial body parts, such as those used for spinal wires and joints).
c) Society requires many of the products of electrochemical cell reactions and electrolysis, but problems of wastes and hazardous by-products must be addressed by both companies and consumers.
d) Electrolysis is an energy-intensive procedure. The benefits derived from its products must be related to its high energy consumption to determine the real benefit of the products to society.
e) Some problems occur because of the spontaneity of electrochemical cell reactions. Some may be "postponed" by industry (e.g., as when nails are galvanized).

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students':

a) construction of electrochemical and electrolytic cells, measurement of voltages, and records of data;
b) discussions or written reports on the industrial benefits of, and societal concerns about, redox chemical processes.

6. Safety Considerations

a) The need for care in the handling of solutions and electrical equipment (e.g., to avoid electrode decay, electrical wiring hazards, and possible electric shocks) should be stressed. A slogan such as "Hands off terminals!" might prove effective.
b) Students should be wary of the sulphuric acid in lead storage cells.

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* See the subsection entitled "Student Activities" on page 6.

c) Half-cells that produce noxious fumes or dangerous by-products (e.g., mercury, sulphur, halogen gases) should not be set up.
d) When using voltage-supply equipment, students should be careful not to exceed the correct voltage. They should be cautioned to disconnect the power supply by pulling the plug, not the cord.

7. Possible Extensions

Some students might:

a) study and prepare other half-cells and combinations;
b) perform a redox titration;
c) investigate the effect of temperature change on chemical cells and discuss the implications;
d) write reports or essays on fuel cells, lithium batteries, or rechargeable batteries.

8. Some Teaching Suggestions

a) The teacher should indicate what is happening in the two separated (half-cell) beakers and discuss the function of the salt bridge. Inferences about its function may be approached initially from "the tendency of things to run down". A more detailed list of definitions related to redox terms may be made.
b) Students should be required to extend the inferences to quantitative calculations. Discussion should focus on various applications of half-cell concentrations in industry, including, for example, concentrations that do or do not work and the suitable choices of metal metal-salt half-cells.
c) The emphasis in this unit is not on the solution of difficult redox equations, but on the ability of students to follow the electron flow in the chemical process. Complex ions, acidic or basic media, and free energy work need not be discussed in this unit.
d) At least once during this unit, students' practical manipulative skills could be evaluated. The teacher could base this evaluation on observation of experimental work in the classroom, which he/she could rate on an "excellent-good-fair-poor" scale. The goal is to make students aware of the difficulties involved in producing accurate quantitative results.
e) Students should be involved in a dialogue on the need for and dangers of certain chemicals. The societal demands for these products, even though they may be accompanied by known hazardous effects, should be emphasized. The difference between the role of research chemists and that of entrepreneurs in developing useful products from scientific research should also be discussed.
f) Students can be taken on a field trip to local industrial plants that utilize electrochemical processes.

Core Unit 7

Independent Investigation

Time: 8 hours

An independent investigation unit has been incorporated as a core unit of this Ontario Academic Course in order to give students an opportunity to apply the techniques and principles of scientific inquiry acquired during their years of formal science training. Chemistry is a good middle ground for such an undertaking. It is necessary for understanding areas of biology and biochemistry, and the analytic approach involved in the study of chemistry complements the study of physics. Since today's students are likely to change jobs several times during their lifetimes, self-reliance, adaptability, and flexibility will be important personal characteristics. Conducting an independent investigation will help students to develop these traits.

A major purpose of this unit is to provide students with opportunities to design and implement an investigative chemistry project; to conduct the experimental work or combine experimentation and a literature search; and to analyse and evaluate chemical information. Where possible, there should be a component based on an experiment performed by the individual student.

Because an independent investigation is tailored to individual students' aptitudes, abilities, and interests, it requires close teacher-student interaction. The topic selected should use and extend the chemical skills the student has developed in this course and in previous science courses. The students should choose the topic in consultation with the teacher. A key function for the teacher in this unit is to keep informed of each student's progress and to provide appropriate direction. Students should be encouraged to develop realistic time lines for the completion of the various tasks, and they should be given opportunities to assess their own progress.

Clear and rational expectations with regard to safety, subject matter, and evaluation should be established. Three possible approaches are suggested in the section "Some Teaching Suggestions".

The teacher may list a variety of topics from which the students would make a selection for an independent investigation. The following set of examples indicates some possibilities.

a) *Consumer items.* Students might test substances to verify claims or to ascertain various characteristics of a material (e.g., pH; strength of fibres; flammability; acid-base reactions: the effectiveness of the material as, for instance, a cleaning agent).
b) *Qualitative analysis.* Students might identify common cations or anions in known or unknown samples.
c) *Quantitative analysis.* This method may be used to determine the composition of various substances. For example, students might determine the per cent by mass of acetic acid in vinegar, molar mass of an unknown acid by titration, K_{sp} value, or sulphate precipitation in a mixture of sodium sulphate and barium chloride.
d) *Separation of substances.* Various materials may be separated physically or chemically and a quantitative amount determined (e.g., the per cent by mass of moisture in a substance, the amount of ash residue after burning, the amount of precipitate formed during selective precipitation).
e) *Heats of reaction.* Previous work may be reinforced (e.g., the use of potassium hydroxide and various acids, the use of mono- and dibasic acids to determine the heat of neutralization per mole of hydrogen ion).
f) *Electrochemical cells.* Students might investigate the use of a sacrificial anode in the process of cathode protection (e.g., using magnesium or zinc to protect iron in various media). This topic is an extension of the work on electrochemical cells.
g) *Extensions.* Any of the ideas stemming from the extensions suggested for either Chemistry, Grade 11, Advanced Level or Chemistry, OAC could be investigated.
h) *Literature search.* Students can do an extensive literature search dealing with current items of concern (e.g., lead poisoning, PCBs, waste disposal, the role of chemistry in genetic engineering).

Note: Because this unit involves an independent activity, the format in which it is written differs slightly from that used in previous units in this course.

1. Objectives

The topics and research approach chosen should develop:

a) students' aptitudes, abilities, and interests;
b) students' ability to apply the techniques and principles of scientific inquiry, problem-solving procedures, divergent thinking, and both oral and written communication skills;
c) a co-operative attitude and interpersonal skills on the part of students;
d) students' confidence in their ability to plan a project and handle chemical data and equipment;
e) students' persistence, ingenuity, initiative, respect for detail, care in gathering data, and pride in work well done.

2. Student Activities

Students are expected to bear the major responsibility for planning and implementing their investigations. They must address the following tasks:

*a) finding and refining the question to be studied;
*b) investigating various ways to answer the question;
*c) selecting and proceeding with the best alternative;
*d) (i) designing an experiment, with safety and controls, if required *or* (ii) planning the approach to a literature search *or* (iii) doing both (i) and (ii);
*e) collecting and checking data and recording them in an organized manner;
*f) analysing and evaluating the collected information in terms of the hypothesis or question proposed in the project;
*g) presenting the scientific conclusions in a manner acceptable to both themselves and the teacher.

3. Applications

Students should provide direct and associated applications related to their investigations.

4. Societal Implications

Students should consider the societal impact of the topics they investigate.

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* See the subsection entitled "Student Activities" on page 6.

5. Evaluation of Student Achievement

Student evaluation for this unit should be based on students' demonstrated ability to:

a) plan their investigations;
b) perform the relevant laboratory work and check the results or use controls where necessary;
c) evaluate the results;
d) present a report in an acceptable form.

6. Safety Considerations

Safety assumes a vital role in independent investigations because the unexpected is more likely to occur in this situation than in traditional practical work. Through vigilance and attention to detail, teachers can ensure safety during independent investigations. Students should be required to submit a safety report prior to doing their experimental work.

7. Possible Extensions

These are not applicable to this unit of study.

8. Some Teaching Suggestions

General Approaches – Science Project Model

- If facilities and time are available, the independent investigation can be done as a "science project" unit involving a good deal of experimental work. In such cases, students would create a working model or an experimental design to answer a specific hypothesis.
- Students might do an in-depth literature search to answer a hypothesis or question of a chemical nature. The result would be a well-organized essay involving an extensive compilation of data and a complete bibliography. In such cases students would probably make a class presentation of their work.
- A blend of the preceding approaches would also be appropriate.
- The teacher should assign the unit early in the course rather than treating it as a terminal activity.
- Each student should keep a log of such things as time spent, contacts made, and experiments performed.

General Suggestions

- Laboratory-centred projects should be encouraged but are not mandatory.
- The teacher may involve the class in planning the evaluation scheme to be used for this unit.
- Two or more students might share a complex project. However, the teacher will need to exercise great care in determining and evaluating the contribution that each student has made to the overall investigation.
- The teacher may wish to provide students with a limited number of projects from which to choose in order to control the number of activities being run concurrently.

Appendixes

Appendixes

A. Science Courses and Their Course Codes

B. The Table of Contents of Part 1

Appendix A

Science Courses and Their Course Codes

The secondary school guideline courses in science authorized under this document have the following course codes:

Science, Grade 9, Basic Level	SNC1B
Science, Grade 9, General Level	SNC1G
Science, Grade 9, Advanced Level	SNC1A
Science, Grade 10, Basic Level	SNC2B
Environmental Science, Grade 10, General Level	SEN2G
Science, Grade 10, General Level	SNC2G
Environmental Science, Grade 10, Advanced Level	SEN2A
Science, Grade 10, Advanced Level	SNC2A
Science, Grade 11, Basic Level	SNC3B
Applied Biology, Grade 11, General Level	SBA3G
Applied Chemistry, Grade 11, General Level	SCA3G
Environmental Science, Grade 11, General Level	SEN3G
Biology, Grade 11, Advanced Level	SBI3A
Chemistry, Grade 11, Advanced Level	SCH3A
Science, Grade 12, Basic Level	SNC4B
Environmental Science, Grade 12, General Level	SEN4G
Geology, Grade 12, General Level	SGE4G
Applied Physics, Grade 12, General Level	SPA4G
Environmental Science, Grade 12, Advanced Level	SEN4A
Geology, Grade 12, Advanced Level	SGE4A
Physics, Grade 12, Advanced Level	SPH4A
Technological Science, Grade 12, General Level	STE4G
Biology, OAC	SBI0A
Chemistry, OAC	SCH0A
Physics, OAC	SPH0A
Science in Society, OAC	SSO0A

The following general rules govern science course codes:

- All science course codes begin with an **S.**
- **SNC** identifies a course that has only the name "Science".
- Where one word other than "Science" describes the course, the first two letters of that word follow the **S** (e.g., **SBI** means "Science, Biology" or simply "Biology"; **SEN** means "Science, Environmental" or "Environmental Science").
- Where two words other than "Science" describe the course, the initial letters of those words are used (e.g., **SCA** means "Science, Chemistry Applied" or simply "Applied Chemistry").
- The fourth character in the course code, **1**, **2**, **3**, **4**, or **0**, represents Grade 9, 10, 11, 12, or an OAC respectively.
- The fifth character represents the level of difficulty: **B** for basic, **G** for general, or **A** for advanced.

For further information on course codes, refer to the *Manual for the Common Course Code* (Toronto: Ministry of Education, Ontario, 1986).

Appendix B

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Appendixes

A. Science Courses and Their Course Codes
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